

DRAWINGS ATTACHED

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**(54) IMPROVEMENTS IN OR RELATING TO THE
TREATMENT OF MEDIUM AND HIGH VISCOSITY
POLYMER MATERIALS**

- (71) We, SNIA VISCOSA SOCIETA' NAZIONALE INDUSTRIA APPLICAZIONI VISCOSA, an Italian Joint-Stock Company, of 18, Via Montebello, Milan, Italy, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- 5 This invention relates to a process for and apparatus for treating medium and high viscosity polymer materials, during the preparation of high polymers for their intended use.
- 10 As is well known, particular conditions and requirements have to be met when performing said treatments; in addition, mechanical equipment which is adapted to process highly viscous compounds has to be used. It is also known that such treatments usually involve the separation or removal from the medium and high viscosity bulk product, of volatile fractions or compounds which are already present, or are being
- 15 formed within the bulk product, and which can be volatilised under the temperature and pressure conditions at which the treatment is performed.
- 20 Treatments which are carried out under the above conditions are well known in the art. Thus, for example, examples of such treatments which are performed on polymers having a medium or high viscosity, in the range from a few hundred poises, up to values of the order of magnitude of a thousand poises or more, include the intermediate and final polycondensation of polyesters, during which glycol, has to be removed. Another treatment in which the mass being treated exhibits a similar behaviour is the demonomerization or stripping of monomer fractions that are present in polyamides, at the end of polymerisation or copolymerisation processes. Such stripping
- 25 operations may advantageously be performed even on the pastes or mixtures of oligomers and monomers that are obtained as by-products, in order to recover the by-products resulting from the known polymerisation process. Thus, for example, the process and apparatus of the present invention may be advantageously utilized for the treatment of pastes and mixtures obtained in the recovery of polycaproadamides by aqueous washing and which consist mainly of low oligomers of the polymer in which the monomer is present in amounts ranging from 20% up to 50%. By means of the process and apparatus of the present invention, it is possible to perform the separation of monomer from the oligomer fraction, which in turn can be simultaneously depolymerised. In general, the present invention can be advantageously applied to treatments involving the removal of a volatile fraction from a polymerised mass, having a viscosity such as will cause a slowing-down of the spontaneous phenomena and the flow of the mass, as well as of migration of the particles of volatile compound which tend to migrate to the surface of viscous mass and there separate.
- 30 Such treatments generally require the use of mechanical means operating within an enclosed space that is kept at a suitable temperature and under a sub-atmospheric pressure (usually of an order of magnitude of a few mm Hg) in order to promote the evaporation of volatile compounds. Said mechanical means are designed to cause stirring of the viscous mass, in order to ensure the required mass transfers, as well as to obtain a more or less efficient alternation of the different portions of the mass at the surface thereof, from which portions the evaporated volatile fractions are separated. The same mechanical means are also usually used to cause the mass which is being processed, to flow across between the inlet and outlet passages respectively for the mass.
- 35 Many kinds of mechanical means have been proposed to obtain the effects specified above. The technical solutions which are at present considered to be the most convenient ones involve the use of one or more screw conveyors, usually fitted with horizontal or

sub-horizontal axes, and partly dipping into the polymer mass. The rotation of such screw conveyors, to the surfaces of which the viscous mass sticks, results in the gradual and repeated transport of portions of the polymer mass towards the surface thereof, thereby promoting the removal of volatile fractions therefrom. Apparatus is also known in which the mass of polymer to be processed is caused to flow by gravity along the inner walls of a suitable container, thus forming a more or less thin layer which travels downwardly towards the outlet of the container. However, no stirring of the polymer mass is provided for in such apparatus and even a controlled flow of the mass toward the container outlet cannot be ensured. Although such known apparatus and in particular screw conveyors, are nowadays considered to be most convenient for obtaining the required effects, it has been found that the efficiency of this apparatus can be greatly improved from the viewpoints of both throughput and of production quality. In fact, such already known methods usually require relatively long dwell times, which result in a low throughput. In addition, it has been found that, even with remarkably long dwell times (expressed as the ratio of mass that is present at any moment in the apparatus to the outflow of processed polymer), the desired results are not obtained in the most desirable way. As a matter of fact, the very long dwell times used in such apparatus result in an accentuation of the trend toward heat degradation of the processed materials, which then no longer meet the quality requirements for their further utilization. Thus, for example, the polymers may take on an undesirable yellow or dark colour. Finally, it has been observed that the removal of volatile fractions does not take place with optimum regularity when the above methods are used. Thus, for example, in the case of screw conveyors, owing to high viscosity of the material the internal motion does not take place with the required uniformity at all points in the whole mass because the distribution of particles and the distances covered by them to reach the surface exposed to the surrounding atmosphere are neither similar, nor uniform. Further undesirable phenomena—for example, those resulting in a non-uniformity of molecular weight—are a consequence of the non-uniformity of processing of different portions of polymer mass.

It is an object of the invention to provide a process of performing chemical treatments of the kind previously referred to, wherein the viscous mass is mechanically processed and manipulated in such a manner as to show a proportionally large exposed surface for the removal of volatile fractions, and to regularly and uniformly bring each portion of the

material into the required condition of exposure of the material.

According to the invention, there is provided a process for the treatment of a medium or high viscosity polymer material to separate a volatile component or components therefrom comprising the steps of distributing the viscous material on a substantially vertical heated cylindrical surface over which the material flows in the form of a viscous film, stirring and redistributing said material so as to bring different portions of the material successively to the surface of the film by means of at least one movable body, the surface of which co-operates with said cylindrical surface, and to which a combined rotary and revolutionary motion is imparted in such a manner that an essentially cycloidal relative motion is established between the stationary and moving surfaces, the surface of said movable body or of at least one of said movable bodies being provided with a spiral groove, and removing said volatile component or components by evaporation during said treatment.

By the use of the invention, conditions of controlled and uniform flow of viscous material from the inlet to the outlet, or into and out of a processing environment, are ensured. In addition, the conditions under which the material is processed and manipulated, are particularly favourable for the fulfillment of heat exchange and mass transfer phenomena, as is required for the transformation of state of volatile fractions, or for accomplishing particular chemical phenomena in particular, polycondensation phenomena.

When the invention is applied to demonomerisation treatments, the treatment is effected with such a high degree of completeness, i.e. with a so low a final monomer content, that the processed polymer can be directly used in commercial production, e.g. of filaments or fibres, to produce optimum properties, without requiring further washings and other treatments.

Thus, for example, polyamides of the Nylon 6 type, having a monomer content of above 9% and produced by the continuous polymerisation of caprolactam, can be quickly and satisfactorily demonomerized in accordance with the invention, until their monomer contents are reduced to 1-2%. The polymers so obtained could therefore be directly spun, giving filaments and fibres showing all the properties required for such products.

By the use of the same equipment in the final polymerisation steps in the production of linear polyesters, an amount of ethylene glycol can be removed from the starting material having an intrinsic viscosity (μ) of 0.3-0.35, such that the processed material

shows at the outlet of the apparatus, a viscosity (μ) of 0.63-0.65; the product is suitable for subsequent extrusion through spinnerets and conversion into polyester filaments and fibres having optimum physical and textile properties.

5 In the process of the invention, the polymer is bound to take the form of a viscous film, sticking to, and flowing along a
10 heated surface, the film being submitted to a mechanical action by which the flow of the film along the surface is caused and controlled, and the material is simultaneously stirred throughout its whole cross-section in
15 order to bring all the portions thereof to the film surface, thus ensuring a thorough mixing and homogenization of the viscous polymerized mass. In conclusion, by the process of the invention, rigorously uniform conditions
20 of feeding, heating and exposure are positively ensured for all portions of the processed mass, while all the volatile fractions are quickly and uniformly removed from all parts of the processed mass.

25 The apparatus used for carrying out the process of the invention may comprise at least one substantially cylindrical heatable metal surface mounted vertically within a tightly closed chamber
30 the temperature and pressure prevailing within which can be controlled, and on which surface or surfaces a viscous film can be formed; means for feeding material to be treated to the top of said
35 surface or surfaces; at least one spirally grooved body located within and cooperating with said surface and supported by and adapted to be driven about a shaft the axis of
40 which is eccentric to the axis of said surface or surfaces and to the axis of which shaft a revolutionary movement about the axis of said surface or surfaces can be imparted,
45 in order to establish conditions of cycloidal motion of said body or bodies with respect to said surface or surfaces; and means for removing evaporated volatile components from said chamber.

Thus, the apparatus may comprise at least one essentially cylindrical metal surface
50 located within a tightly closed chamber, kept under suitable temperature and pressure conditions, the metal cylinder or cylinders having a vertical axis and being suitably heated, while a viscous film is caused to flow on the surface thereof. Supported and driven
55 within the chamber is a cylindrical body designed to perform an essentially cycloidal motion in contact with the surface. The surface of the cylindrical body is provided
60 with spiral grooves, having a pitch and a section such that, as a result of the cycloidal motion, the viscous film is cyclically and continuously subdivided into single portions, distributed across the generatrices of the first
65 surface, and moved forward as a function of

the pitch of the spiral grooves and of the relative rotary motion of the body against the surface, while the periodic and repeated redistribution of polymerised material of
70 which the film is formed into fractions or portions by which the grooves in said body are instantaneously and wholly filled, results in a motion of viscous portions of the film, and in a cyclic transport thereof to the
75 surface of the same film.

Advantageously, the apparatus includes at least two co-axial and superposed, essentially cylindrical surfaces of which the lower has a lesser diameter, each of said surfaces being
80 designed to co-operate with at least one body hypocycloidally driven into contact therewith.

The gearing may be of the cycloidal type, in order to obtain from a single prime mover both the rotational and the revolutionary
85 motions of the cycloidally driven body or bodies working in contact with the surface or surfaces whereon the viscous film is formed and flows.

Alternatively, the gearing may be formed by two mechanical groups in order independently to obtain the rotational and revolutionary motions respectively; thus, changes can be made in the resultants of said
90 motions, in order to pre-set to the extent which appears to be most suitable in each case, the value of sliding motions between the surfaces which are momentarily into contact.

Advantageously, the apparatus may comprise a plurality of co-axial and concentric stationary surfaces, each of which is associated with means for feeding the viscous material to be processed in the form of
100 as many viscous films thereon, and a corresponding plurality of surfaces also 105 co-axially arranged and formed on a structure supported by, and revolving round an axis eccentric in respect to the axis of the first-mentioned surfaces, and to which a revolutionary motion round the latter axis is
110 imparted. Thus, each movable surface will travel through a cycloidal path around its mating stationary surface. In this way, there can be obtained for the same overall size of
115 apparatus and of volume of the processing chamber, a much larger area of the surfaces whereon the viscous film is formed and processed.

Advantageously, said surface or surfaces can be slightly tapered, the body or bodies co-operating therewith being supported in
120 such a manner as to automatically adapt themselves to the taper, and the means by which the co-operating body or bodies are supported can be moved and adjusted along
125 the axes of the surface or surfaces, in order to allow a pre-setting and adjustment of the pressure, or at least of the condition of sliding-rolling contact between said body or bodies, and said surface or surfaces.
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The invention will now be further described with reference to the accompanying drawings, in which:—

5 Figure 1 is a structurally simplified side view, partly in section, of one form of apparatus for use in the present invention;

Figure 2 is a schematic perspective view of part of the apparatus of Figure 1;

10 Figures 3 to 5 are similar diagrammatic side sectional views of a part of the apparatus of Figure 1 on an enlarged scale to illustrate the effect on a viscous film at different moments in its processing;

15 Figure 6 is a diagram illustrating the effects of the processing of a viscous film in the apparatus of Figure 1;

Figure 7 is a diagram illustrating the flow of viscous material through the apparatus of Figure 1;

20 Figure 8 is a diagram illustrating the cycloidal path of the rotating cylindrical body of Figure 1;

Figure 9 is a structurally simplified side view, partly in section, of an alternative form of apparatus for use in the present invention;

25 Figure 10 is a section taken along the line X-X of Figure 9; and

Figure 11 is a diagrammatic perspective view of parts of the apparatus of Figures 9 and 10.

30 In the embodiment shown in the Figures 1 and 2, the apparatus comprises a structural assembly which, at least in its middle and bottom sections, may be considered as a vertical axis reactor for a final polycondensation. Inside the reactor are two coaxially superposed chambers 10 and 11 the walls 12 and 13 respectively of which are slightly tapered downwardly for the purposes stated hereinafter, and are connected with one another by an annular section 14. The walls, which are preferably made of stainless steel, are heated by a suitable heat carrier, e.g. diphenyl, which is circulated through a space 15 between the outer faces of the walls 12 and 13 and a jacket by which the walls and, if needed, inlet and outlet pipe connections 16 and 17 respectively for the polymer are surrounded. These pipe connections 16 and 17 lead respectively to at least one inlet orifice 18 for the polymer at the top of wall 12 of the upper chamber, and to a sealed removal means, e.g. a screw conveyor 19 at the bottom of the lower chamber. The apparatus also comprises an outlet duct 43 for the removal of vapours of volatile material.

55 Within the limits of the above description, and assuming that the polymer mass or mixture, or other viscous material be fed to the top of the wall 12, such material when flowing downwardly by gravity would form uncontrollably superposed layers, i.e. a composite film which in the long run should take up a thickness such as would interfere

with the uniform heating thereof, as well as with the removal of volatile fractions. In fact, the natural downward flow is governed by the value of the cohesive and adhesive forces which oppose the action of gravity, and are modified proportionally to the changes in the viscosity of polymer while this latter is flowing along said wall.

70 Coaxially fitted cylindrical bodies 20 and 21 provided externally with spiral grooves, are fitted into contact with the walls 12 and 13 respectively, in such a manner as to roll thereon. The bodies 20, 21 are supported by a ball joint 22 and a shaft 23, that in turn is rotatably mounted on a suitable supporting structure which, in the embodiment illustrated consists of a pair of arms 24, pivotally mounted on a driving shaft 25 which is coaxial with said chambers, and which extends out of the head 26 of the reactor through a suitable vacuum sealing system 27, in order to allow the required high vacuum of a few mm Hg. to be produced and maintained with said chambers.

85 The driving shaft 25 is connected with a suitable prime mover (not shown) e.g. by a belt transmission and a pulley 28, and is also rigidly connected with the sun gear 29 of a planetary gearing, including a planet wheel 30, that is mounted coaxially on the shaft 23 by which the bodies 20 and 21 are supported and is in mesh with a crown gear 31, keyed to the casing of device. The planet wheel 30 is preferably rotatably mounted on the shaft 23, on which shaft 23 is rigidly keyed a second planet gear 32, that is in mesh with a second sun gear 33 carried by the shaft 25. Such doubling of the epicycloidal system has been adopted for the double purpose of allowing a relative angular velocity different from that of the planet wheel 30 while rolling round the crown gear 31 to be imparted to the bodies 20 and 21 by suitably selecting the gear ratios, and of distributing over both gears the stresses resulting from the resistance that is to be overcome in the course of the respective revolutionary and rotary motions of the bodies 20 and 21.

100 The various gears and shaft bearings are enclosed within a housing 40 that is separated from the processing space by a disc-shaped diaphragm 41, having a seal through which extends the eccentric shaft 23, and being sealed against the chamber wall by a labyrinth seal. Owing to the practical impossibility of ensuring a really tight seal, an atmosphere of nitrogen, introduced through a passage 42, can advantageously be maintained within the housing 40, whereby the environment in which the processing is carried out is not polluted by possible leakages of gas thereinto.

115 The driving shaft 25 is also engaged with means by which it can be axially adjusted, in the embodiment illustrated a hub 34 which is

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screwed in a frame 35 secured to the head 26 of the apparatus housing.

Since the wall surfaces 12 and 13 are similarly tapered, the axial adjustment of the shaft 25, from which the whole movable assembly depends, allows the adherence conditions between the bodies 20, 21 and the surfaces 12 and 13 to be accurately established, while the ball joint 22 allows the bodies 20, 21 to automatically take the inclination required to ensure adhesion with surfaces, thereby compensating for the unavoidable manufacturing tolerances possible distortions or strains, and the like.

The conditions by which the course of the material being processed according to the invention is governed, are a consequence of the hypocycloidal motion (which may involve slipping between the surfaces 12, 13 and the bodies 20, 21, depending on the transmission ratios of the gears) and of the presence of spiral grooves on the surface of the bodies, the direction of the spiral of the grooves being selected in such a manner as to generate a downwardly directed component as an effect of their combined rotary and revolutionary motions in contact with the surfaces of chambers 10 and 11.

The profile of the grooves is preferably similar to that shown in schematic Figures 3 to 5, except for a ratio of depth to axial development of the groove less than that shown in the figures. The groove width should be approximately $\frac{2}{3}$ of the pitch of the spiral, while the groove depth gradually increases from the top to bottom of the bodies. These dimensional configurations can obviously be changed in accordance with the nature and viscosity of the material to be processed.

The effects ensuing from the co-operation of the spirally grooved bodies with the surfaces 12 and 13, against which they roll, are also diagrammatically shown in Figures 3 to 5.

The profile of the grooves is so dimensioned that the material present on the surfaces can be accommodated within their useful sections. The hypothetical distribution of a polymer P, in the form of a viscous film having a uniform thickness sp , and adhering to one of the surfaces, e.g. to surface 12, is shown in Figure 3. Thus, for a given height h of film, the area of the section of material is given by the product $h \cdot sp$. The sectional area A of each groove is such that the sum of such areas present within the given height h of the viscous film, is equal to the $h \cdot sp$ product. Thus, by assuming that the section is reproduced on the generatrix at which an instantaneous contact occurs between the body 20 and the surface 12 (as shown in Figure 4), then the material of the viscous film will enter into the grooves of the body 20, filling the whole section thereof. After

said body is passed over anyone of the generatrices of its surface, the liquid film, previously subdivided into superposed portions A (see Figure 4), starts to flow downwardly, at a rate determined by its viscosity, thus taking a form which in its vertical section is similar to that shown and indicated at A'' in Figure 5, whereafter it is again subdivided and redistributed into portions A', by the next passage of the body 20 or 21.

The possible occurrence of slipping phenomena, successively at each passage, is diagrammatically shown in Figure 6. By assuming that the polymer portions A', that the flow out of the grooves of the rolling body, are subdivided into a plurality of superposed thin films, individually indicated by the arrows F in Figure 6 then by the known laws of the motion of viscous fluids, these films will flow at gradually increasing speeds under the action of gravity the speed being greater the farther the individual layer is from the surface 12 to which the limiting layer is sticking. Thus, the particles of underlying polymer are gradually uncovered by the overlying ones. The next passage of the rolling body during which the conditions shown in Figure 4 are re-established by cutting the viscous layer down to its limiting film and filling the groove sections, results in an efficient mixing of the material and in an alternation of the portions that are present at the surface of the viscous film.

At the same time, the axial component of the pitch of the spiral groove causes a forced downward motion of the viscous layer, within the arc of the circle defined by its instantaneous interference with the grooves of the rolling bodies.

Consequently, a controlled downward progression of the viscous film, as diagrammatically shown in Figure 7, is attained. Included in this downward progression is a mixing step which occurs when the film passes over the annular section 14, and is completed within the lower chamber 11. Obviously, this forced downward progression can be adjusted at will, as a function of the speed at which the rolling assembly is driven, and of the pitch of the spiral grooves of the rolling bodies.

Moreover, by making up the gearings with toothed wheels having mutually prime numbers of teeth, a change in the contact conditions and meshing positions will occur at each revolution. The epicycloidal evolution of each point of the rolling bodies with regard to the surfaces against which they are rolling, takes the course as shown diagrammatically in Figure 8, in which the case is exemplified in which a negative slipping N occurs, during the arc of contact, with regard to the direction D of revolution, which slipping may obviously be even

positive or nil, should the diametral pitch of the crown gear 31 be greater or equal to that of the surface 12, or gears 29, 30 and 33, 32 respectively with different transmission ratios be utilized.

The ratio of chamber diameter to diameter of the rolling body working in the chamber is so selected as to obtain the required length of the arcs of circle across which the viscous film becomes engaged with the spiral grooves of the body. Similarly, two or more rolling bodies working in each chamber and suitably arranged in order to simultaneously act on equidistant generatrices of the respective surface, can be used.

The apparatus according to the invention has experimentally proved to be capable of meeting the purposes of the invention, in a satisfactory way. Amongst the main operating advantages of the above described apparatus are the following:—

The mechanical action, as exerted under the stated conditions, allows the highly viscous material to be distributed in the form of a well defined layer over a very large surface, thus showing a large exposed surface area.

This layer is continuously and thoroughly mixed and homogenized by the combined action of lamination and drawing which is exerted by the spirally grooved rolling bodies, whereby each portion of the material is repeatedly exposed at the layer surface, which results in a really uniform treatment of all portions of the polymer.

The downward flow of the layer occurs in a uniform and strictly controlled manner. Thus, the dwell time of the material in the processing environment can be efficiently controlled, and in the course of such time each portion of the material will be periodically brought under the conditions which are the most favourable for the removal of volatile fractions.

The apparatus permits wide variations in the processing conditions, owing to the possibility of changing the dimensional parameters, the gearing transmission ratios by which the conditions of hypocycloidal movement are determined, with consequent, combined relative rolling and sliding motion and so on, and finally by merely changing the angular speed imparted to the driving shaft, according to which the frequency with which each portion of the polymer is subjected to mechanical action will vary, and the speed of forced flow of the viscous layer along the walls from which heat is taken up by it.

In an alternative form of apparatus according to the invention, mechanical means are provided by means of which the motions of rotation and revolution can be independently imparted to a plurality of movable surfaces, and a plurality of stationary, coaxially fitted surfaces is used. Such

an alternative form of apparatus as shown in Figures 9, 10 and 11 (wherein the parts and the components are either structurally shown, as in Figures 9 and 10, or diagrammatically shown, as in Figure 11 and are indicated by the same reference numerals).

The processing chamber consists of the inside of a casing 50, suitably surrounded by a spaced jacket 51, through which a heat carrier, e.g. diphenyl, is circulated. The inner side 52 of the casing 50 forms a first flowing surface to which the material to be processed is fed through a duct 53 that is connected with an annular passage 54, which in turn is connected with the inside of the chamber through a crown of radial passages. Working against the surface 52 is the outer surface 55 of an essentially cylindrical component 56 which forms part of a movable assembly 57, supported and driven as hereinafter described. The inner surface 58 of the component 56 is designed to co-operate with the outer surface 59 of an inner stationary body 60, fitted coaxially with the casing 50. The inner surface 61 of the body 60 is designed to co-operate with the outer surface 62 of an inner component 63 of the movable assembly 57. Spiral grooves are formed in the working surfaces of the components 56 and 63 of the movable assembly 57. By means of ducts 64 and 65, annular passages and crowns of holes, the material to be processed is also fed to the top of the inner and outer stationary surfaces 59 and 61 respectively, of the stationary body 60.

The stationary and movable cylindric bodies, the thickness thereof and the diametral sizes of said surfaces, are selected in such a manner that, by imparting a determined eccentricity to the assembly 57 in respect of the stationary components of the apparatus, the mating stationary and movable surfaces 52 and 55, 58 and 59, 61 and 62, are brought into mutual tangential contact along one of their generatrices.

Thus, by imparting to the axis of the movable assembly 57 a revolutionary motion, with said eccentricity around the axis of the stationary components 50 and 60, each movable surface will cover a cycloidal path in respect of the mating stationary surface, and such motion is completed by imparting to the assembly 57 a rotary motion about its own axis, which is continuously moved in the interspace.

As can be readily appreciated, such a plurality of co-operating surfaces allows a very large area of total surfaces to be obtained, and thus a very large surface whereon the material can be exposed to the processing environment. By way of example and assuming that the diameter of the larger stationary surface 52 to be one metre then apparatus having the proportions as shown in Figures 9 and 10 will show a useful

processing surface of 12 sq.m for each metre of height of the surface—obviously taking into account that the viscous film is transferred and formed on the movable surfaces also.

The above described stationary and movable surfaces also show the advantageous feature of a slight downward taper, for the purposes set forth above. Steps are also advantageously formed in the lower section of the apparatus and the lower surfaces show a proportionally reduced diameter, again for the purposes previously stated.

The apparatus is completed by suction ducts 69 for the removal of the inner atmosphere, i.e. of volatile components that are given off by the processed material, by means for discharging the wholly treated material through the bottom of the casing and by means for the metered feed of material to be processed to the ducts 53, 64 and 65, the amount of fed material obviously being proportioned to the area of the related surfaces.

The movable assembly 57 is supported and driven by a Cardan joint 70, fitted to the lower end of a strong shaft 71, that in turn is supported by a hub 73, and extends eccentrically therethrough with the aid of a tight seal 72, said hub 73 being mounted coaxially with the stationary surfaces and rotatably supported in a top frame 74, also tightly sealed against loss of the processing environment, by means of a suitable packing, e.g. a stuffing box 75.

The upper end 71' of the shaft 71 is secured to a bell gear 76, the inner toothing of which is in mesh with a pinion 77, keyed to a shaft 78, co-axial with the stationary surfaces, and driven by a transmission including a pulley 79. Thus, the required rotary motion around the shaft 71, can be imparted to the movable assembly 57, whatever may be the momentary position of this shaft in the course of the revolutionary motion of the assembly.

The revolutionary motion of the assembly 57 is imparted by means of a separate mechanism, which comprises a driven gear 80, keyed to the hub 73 by which the shaft 71 is eccentrically supported, and a driving gear 81 keyed to a shaft 83 that is in turn driven through a pulley 83.

Thus, the two rotary and revolutionary motions can be independently imparted by driving the pulleys 79 and 83 respectively, to establish at will the conditions (with or without slipping) of cycloidal motion, and also to set the value of slipping required between the cycloidally engaged surfaces.

Obviously, the pulleys 79 and 83 may be driven by separate motors, fitted with the necessary variators. For simplicity's sake, however, recourse may be had to a single motor for driving both pulleys, the ratio of rotary motion to revolutionary motion then

being established by the use of pulleys having a suitable diameter; in this case it is possible to change the ratio, when required, merely by substituting one of said pulleys with another having a different diameter.

It may be remarked that in the technical solution illustrated in Figure 9, all the gears and necessary mechanical means are fitted on the outside and are wholly separated from the processing chamber the tight seal of which is ensured by the double packing represented by the stuffing box and equivalent means 72 and 75. Owing to the relatively small diameter of such sealing means, and to the consequently high efficiency thereof, it will be possible to transmit the complex combined motion of rotation and revolution to the inside of the processing chamber, while ensuring a tight seal thereof and the formation and maintenance of a very high vacuum.

WHAT WE CLAIM IS:—

1. A process for the treatment of a medium or high viscosity polymer material to separate a volatile component or components therefrom comprising the steps of distributing the viscous material on a substantially vertical heated cylindrical surface over which the material flows in the form of a viscous film, stirring and redistributing said material so as to bring different portions of the material successively to the surface of the film by means of at least one movable body, the surface of which co-operates with said cylindrical surface, and to which a combined rotary and revolutionary motion is imparted in such a manner that an essentially cycloidal relative motion is established between the stationary and moving surfaces, the surface of said movable body or of at least one of said movable bodies being provided with a spiral groove, and removing said volatile component or components by evaporation during said treatment.

2. A process for the treatment of a medium or high viscosity polymer material to separate a volatile component or components therefrom substantially as hereinbefore described with reference to the drawings.

3. Apparatus for carrying out a process as claimed in Claim 1 comprising at least one substantially cylindrical heatable metal surface mounted vertically within a tightly closed chamber the temperature and pressure prevailing within which can be controlled, and on which surface or surfaces a viscous film can be formed; means for feeding material to be treated to the top of said surface or surfaces; at least one spirally grooved body located within and co-operating with said surface and supported by and adapted to be driven about a shaft the axis of which is eccentric to the axis of said surface or surfaces and to the axis of which

5 shaft a revolutionary movement about the axis of said surface or surfaces can be imparted, in order to establish conditions of cycloidal motion of said body or bodies with respect to said surface or surfaces; and means for removing evaporated volatile components from said chamber.

10 4. Apparatus as claimed in Claim 3 including a means for imparting to said spirally-grooved body or bodies both a rotary motion about its own axis and a revolutionary movement about the axis of said surface or surfaces.

15 5. Apparatus as claimed in Claim 3 or Claim 4 comprising at least two heatable metal surfaces of different diameters located in continuation of one another and connected by stepped-down annular sections, and said spirally-grooved body having at least two sections of different diameters corresponding to said surfaces and each of said sections being arranged for cycloidal motion with respect to the corresponding surface, whereby two successive zones over which the viscous material is allowed to flow whilst being mechanically processed are formed.

30 6. Apparatus as claimed in any one of Claims 3 to 5 wherein said surface or each of said surfaces and the surface of said body or each of said bodies are slightly tapered, and wherein means are provided for the relative axial adjustment of mating whereby the engagement and pressure conditions prevailing between the mating surfaces can be adjusted.

40 7. Apparatus as claimed in any one of Claims 3 to 8 comprising a heated cylindrical surface formed by the inner surface of the wall defining said chamber, and at least one spirally grooved body tangentially engaging said surface and to which a hypocycloidal motion relative to said heated surface can be imparted.

45 8. Apparatus as claimed in Claim 7 comprising a plurality of cylindrical, spirally grooved bodies, uniformly spaced around the axis of said surface and adapted to be driven in such a manner that each of said bodies is moved hypocycloidally relative to said surface.

50 9. Apparatus as claimed in any one of Claims 3 to 6 comprising a plurality of coaxially mounted and radially spaced stationary surfaces, and a movable assembly eccentrically supported in the intervening space between said stationary surfaces and comprising a plurality of coaxially arranged, spirally grooved surfaces, each adapted to cycloidally engage on said stationary surfaces, and means for imparting a combined

rotational and revolutionary motion to said assembly.

65 10. Apparatus as claimed in Claim 9 including separate means for the metered feeding of material to the top of each of said stationary surfaces.

70 11. Apparatus as claimed in any one of Claims 3 to 10, including a gearing for driving the movable body or bodies, or assembly, said gearing being adapted to impart both rotary and revolutionary motions to said body or bodies or assembly.

75 12. Apparatus as claimed in Claim 11, wherein said gearing is an epicycloidal gearing including two planetary systems, by means of which said combined motion is imparted in such a manner as to obtain a relative slipping between the cycloidally engaged surfaces.

80 13. Apparatus as claimed in any one of Claims 3 to 10 including separate means for imparting a rotary motion and a revolutionary motion round the axis of said stationary surface or surfaces respectively to said body or bodies or assembly.

90 14. Apparatus as claimed in Claim 12, comprising a body revolvingly relative to the axis of said stationary surface or surfaces and supporting in turn a shaft in a position eccentric with respect to the axis of said surface or surfaces said shaft being adapted to support and drive said body or bodies, or assembly, means for imparting a rotary motion to said body or bodies or assembly and means for driving said shaft around the axis of said surface or surfaces.

95 15. Apparatus as claimed in any one of Claims 3 to 14 wherein said body or bodies or assembly, is supported by a shaft, to which a combined motion of rotation and revolution is imparted through a ball joint so as to ensure an automatic tangential adaptation of said movable surface or surfaces to said stationary surface or surfaces with which said movable surface or surfaces are cycloidally engaged.

100 16. Apparatus for carrying out a process as claimed in Claim 1 substantially as hereinbefore described with reference to and as shown in Figures 1 to 8, or Figures 9 to 11 of the drawings.

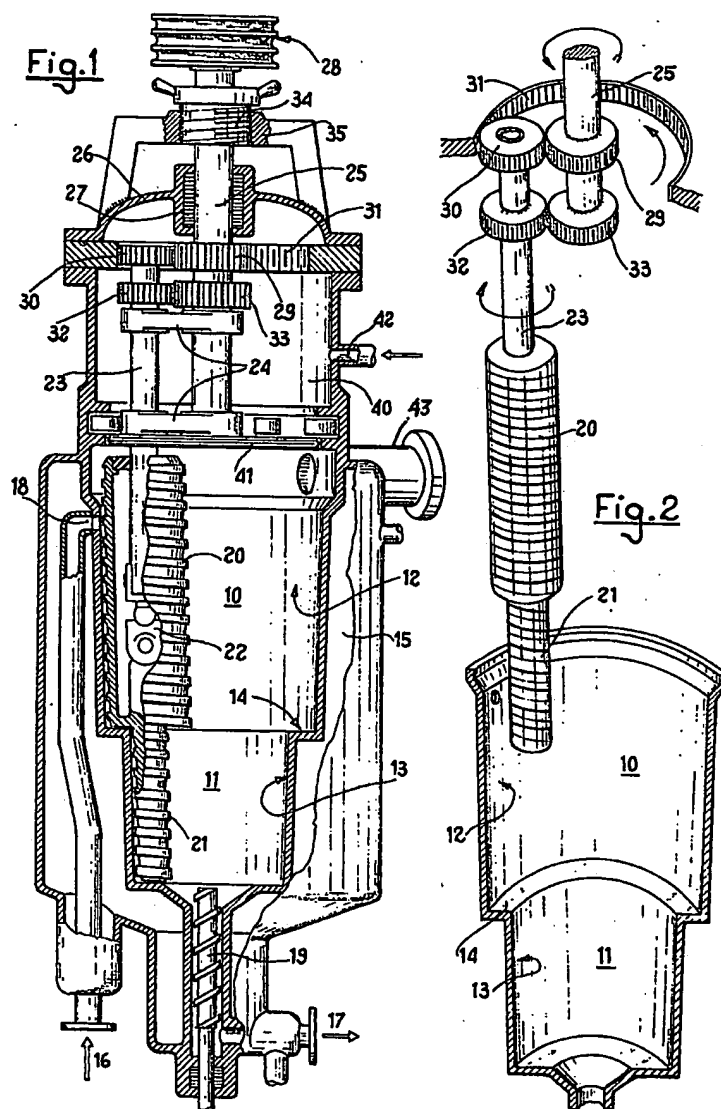
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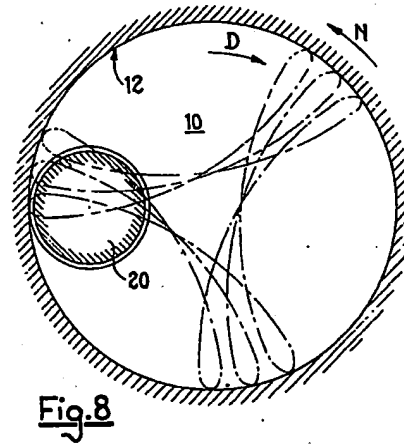
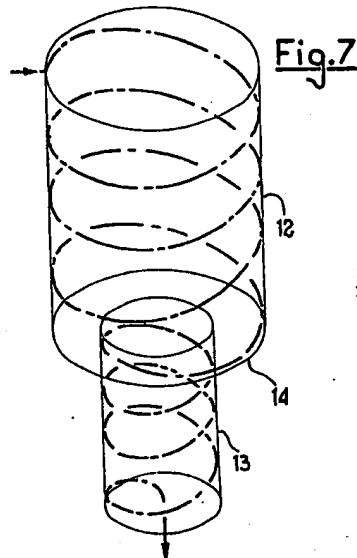
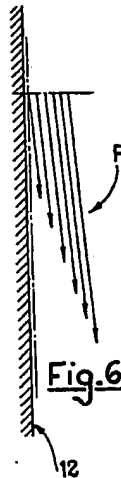
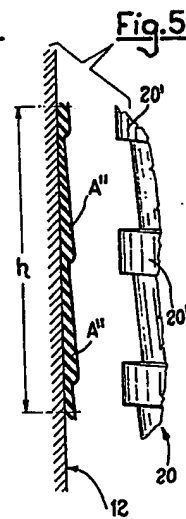
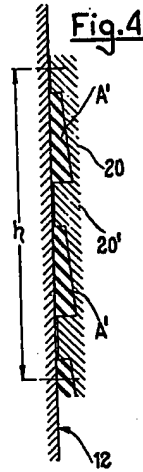
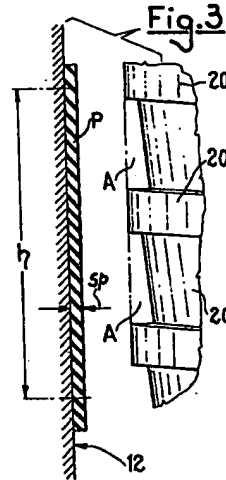
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